We claim:

1. A 4-DOF nonresonant micromachined gyroscope comprising:

a 2-DOF drive-mode oscillator; and

a 2-DOF sense-mode oscillator, where the drive-mode oscillator and sense-mode oscillators are mechanically decoupled and employ three interconnected proof masses.

2. The 4-DOF nonresonant micromachined gyroscope of claim 1 wherein the 2-DOF drive-mode oscillator and 2-DOF sense-mode oscillator utilize dynamical amplification in the drive and sense directions to achieve large oscillation amplitudes without resonance resulting in increased bandwidth and reduced sensitivity to structural and thermal parameter fluctuations and damping changes.

3. The 4-DOF nonresonant micromachined gyroscope of claim 1 wherein one of the three masses is an intermediate proof mass and another is a sensing element, and wherein the 2-DOF drive-mode oscillator and 2-DOF sense-mode oscillator are mechanically decoupled in the drive direction from the sense direction for robustness and long-term stability and to allow the Coriolis force that excites the sensing element to be generated by the intermediate proof mass with a larger mass, resulting in larger Coriolis forces for increased sensor sensitivity so that control system requirements and tight fabrication and packaging tolerances are relaxed, mode-matching is eliminated,

and instability and zero-rate drift due to mechanical coupling between the drive and sense modes is minimized.

4. The 4-DOF nonresonant micromachined gyroscope of claim 1 wherein the 2-DOF drive-mode oscillator and 2-DOF sense-mode oscillator include a drive means for driving a mass in a drive direction and a sense means for sensing motion of a mass in a sense direction, and wherein the three interconnected masses comprise a first, second and third mass, the first mass being the only mass excited by the drive means, oscillating in the drive direction and being constrained from movement in the sense direction, the second and third masses being constrained from movement with respect to each other in the drive direction and oscillating together in the drive direction but oscillating independently from each other in the sense direction, the third mass being fixed with respect to the second mass in the drive direction, but free to oscillate in the sense direction, the first mass as a driven mass and the second and third masses collectively as a passive mass comprising the drive-mode oscillator, the second and third masses comprising the sense-mode oscillator.

5. The 4-DOF nonresonant micromachined gyroscope of claim 4 wherein the second mass oscillates in the drive and sense directions to generate rotation-induced Coriolis force that excites the 2-DOF sense-mode oscillator, a sense direction response of the third mass, which comprises the vibration absorber of the 2-DOF sense-mode oscillator, is detected for measuring the input angular rate.

6. The 4-DOF nonresonant micromachined gyroscope of claim 1 wherein the 2-DOF drive-mode oscillator and 2-DOF sense-mode oscillator comprise a drive means for driving a mass in a drive direction, a sense means for sensing motion of a mass in a sense direction, and a substrate on which the drive-mode oscillator and sense-mode oscillator are disposed, wherein the three interconnected masses comprise a first, second and third mass, where the first mass is anchored to the substrate by a first flexure which allows movement substantially only in the drive direction, where the second mass is coupled to the first mass by a second flexure that allows movement in the drive and the sense directions, and where the third mass is coupled to the second mass by a third flexure which allows movement substantially only in the sense direction.

7. The 4-DOF nonresonant micromachined gyroscope of claim 6 wherein the first, and third flexures are folded micromachined springs having a resiliency substantially in only one direction and wherein the second flexure is comprised of two coupled folded micromachined springs, each having a resiliency substantially in only one of two different directions.

8. The 4-DOF nonresonant micromachined gyroscope of claim 1 wherein the 2-DOF drive-mode oscillator and 2-DOF sense-mode oscillator each have two resonant peaks and a flat region between the peaks, the gyroscope being operated in the flat regions of the drive and sense-mode oscillators.

9. The 4-DOF nonresonant micromachined gyroscope of claim 8 wherein the 2-DOF drive-mode oscillator and 2-DOF sense-mode oscillator are arranged and configured to have matching drive and sense direction anti-resonance frequencies.

10. The 4-DOF nonresonant micromachined gyroscope of claim 1 wherein the 2-DOF drive-mode oscillator and 2-DOF sense-mode oscillator comprise a drive means for driving a mass in a drive direction, and a sense means for sensing motion of a mass in a sense direction, wherein the three interconnected masses comprise a first, second and third mass and coupled flexures, the second and the third masses combining to comprise a vibration absorber of the drive-mode oscillator, which vibration absorber mechanically amplifies the oscillations of the first mass.

11. The 4-DOF nonresonant micromachined gyroscope of claim 10 wherein the first mass is driven at a driving frequency, ω_{drive}, by means of a input force F_d, which driving frequency, ω_{drive}, is matched with the resonant frequency of an isolated passive mass-spring system comprised of the second and third masses and coupled flexures, which passive mass-spring system moves to cancel out the input force F_d applied to the first mass, so that maximum dynamic amplification is achieved.

12. The 4-DOF nonresonant micromachined gyroscope of claim 1 wherein the 2-DOF drive-mode oscillator and 2-DOF sense-mode oscillator comprise a drive means for driving a mass in a drive direction, and a sense means for sensing motion of a mass in a sense direction, wherein the three interconnected masses comprise a first, second

and third mass and coupled flexures, where the third mass acts as the vibration absorber in the sense-mode oscillator to achieve large sense direction oscillation amplitudes due to mechanical amplification.

13. The 4-DOF nonresonant micromachined gyroscope of claim 12 wherein a sinusoidal Coriolis force is applied to the second mass, and where the frequency of the sinusoidal Coriolis force is matched with a resonant frequency of the isolated passive mass-spring system of the third mass and its coupled flexures, so that the third mass achieves maximum dynamic amplification.

14. The 4-DOF nonresonant micromachined gyroscope of claim 1 wherein the 2-DOF drive-mode oscillator and 2-DOF sense-mode oscillator comprise a drive means for driving a mass in a drive direction, and a sense means for sensing motion of a mass in a sense direction, wherein the three interconnected masses comprise a first, second and third mass and coupled flexures, wherein the frequency response of both the drive-mode oscillator and sense-mode oscillator have two resonant peaks and a flat region between the peaks, wherein both of the drive-mode oscillator and sense-mode oscillator are operated in the flat region of their response curves, and where the drive anti-resonance frequency, ω_{2x}, of the second mass and sense anti-resonance frequency, ω_{3y}, of the third mass are matched, namely where $\omega_{3y} = \omega_{2x}$, or equivalently $(k_{3y}/m_3)^{1/2} = (k_{2x}/(m_2 + m_3))^{1/2}$ determines the optimal system parameters, together with the optimized ratios $\mu_x = (m_2 + m_3)/m_1$, $\gamma_x = \omega_{2x}/\omega_{1x}$, $\mu_y = m_3/m_2$, and $\gamma_y = \omega_{3y} / \omega_{2y}$, where k_{3y} is the spring constant of the flexures coupled to the third mass, where m_3 is the magnitude of

the third mass, k_{2x} is the spring constant of the flexures coupled to the second mass, m_2 is the magnitude of the second mass, m_3 is the magnitude of the third mass, ω_{1x} is the drive anti-resonance frequency of the first mass, and ω_{2y} is the sense anti-resonance frequency of the second mass.

15. A method of operating a 4-DOF nonresonant micromachined gyroscope comprising:

driving a 2-DOF drive-mode oscillator with an applied force;

driving a 2-DOF sense-mode oscillator with a Coriolis force derived from the 2-DOF drive-mode oscillator; and

mechanically decoupling the drive-mode oscillator and sense-mode oscillators.

16. The method of claim 15 wherein driving the 2-DOF drive-mode oscillator and driving the 2-DOF sense-mode oscillator dynamical amplifies motion in the drive and sense directions to achieve large oscillation amplitudes without resonance to result in increased bandwidth and reduced sensitivity to structural and thermal parameter fluctuations and damping changes.

17. The method of claim 15 where mechanically decoupling the drive-mode oscillator and sense-mode oscillators comprises mechanically decoupling the drive-mode oscillator and sense-mode oscillators in the drive direction from the sense direction for robustness and long-term stability and exciting a sense element in the sense-mode oscillator by a Coriolis force generated by an intermediate proof mass employed in both

the drive-mode and sense mode oscillators, the intermediate proof mass being provided with a larger mass than the sense element, resulting in larger Coriolis forces for increased sensor sensitivity so that control system requirements and tight fabrication and packaging tolerances are relaxed, mode-matching is eliminated, and instability and zero-rate drift due to mechanical coupling between the drive and sense modes is minimized.

18. The method of claim 15 wherein driving the 2-DOF drive-mode oscillator and driving the 2-DOF sense-mode oscillator comprises driving a mass in a drive direction and sensing motion of a mass in a sense direction, and wherein the 2-DOF drive-mode oscillator and the 2-DOF sense-mode oscillator comprise three interconnected masses namely a first, second and third mass, exciting the first mass only by a drive means, oscillating the first mass in the drive direction with a driving force and constraining movement of the first mass in the sense direction, constraining movement of the second and third masses with respect to each other in the drive direction, oscillating the second and third masses together in the drive direction but oscillating the second and third masses independently from each other in the sense direction, the third mass being fixed with respect to the second mass in the drive direction, oscillating the third mass in the sense direction, the first mass as a driven mass and the second and third masses collectively as a passive mass comprising the drive-mode oscillator, the second and third masses comprising the sense-mode oscillator.

19. The method of claim 18 wherein oscillating the second mass in the drive and sense directions generates a rotation-induced Coriolis force that excites the 2-DOF sense-mode oscillator, and detecting a sense direction response of the third mass, which comprises the vibration absorber of the 2-DOF sense-mode oscillator, for measuring the input angular rate.

20. The method of claim 15 wherein the 2-DOF drive-mode oscillator and 2-DOF sense-mode oscillator comprise a drive means for driving a mass in a drive direction, a sense means for sensing motion of a mass in a sense direction, and a substrate on which the drive-mode oscillator and sense-mode oscillator are disposed, wherein the three interconnected masses comprise a first, second and third mass, further comprising anchoring the first mass to the substrate by a first flexure and moving the first mass substantially only in the drive direction, moving the second mass coupled to the first mass by a second flexure in the drive and the sense directions, and moving the third mass coupled to the second mass by a third flexure substantially only in the sense direction.

21. The method of claim 20 further comprising coupling the first, second and third masses by the first and third flexures by providing folded micromachined springs having a resiliency substantially in only one direction and by the second flexure which is comprised of two coupled folded micromachined springs, each having a resiliency substantially in only one of two different directions.

22. The method of claim 15 wherein driving the 2-DOF drive-mode oscillator and driving 2-DOF sense-mode oscillator comprises operating the gyroscope in the flat regions of the drive and sense-mode oscillators between two resonant peaks.

23. The method of claim 22 further comprising matching drive and sense direction anti-resonance frequencies of the 2-DOF drive-mode oscillator and 2-DOF sense-mode oscillator.

24. The method of claim 15 wherein the 2-DOF drive-mode oscillator and 2-DOF sense-mode oscillator comprise a drive means for driving a mass in a drive direction, and a sense means for sensing motion of a mass in a sense direction, wherein the three interconnected masses comprise a first, second and third mass and coupled flexures, the second and the third masses combining to comprise a vibration absorber of the drive-mode oscillator, further comprising mechanically amplifying the oscillations of the first mass by means of the vibration absorber.

25. The method of claim 24 further comprising driving the first mass at a driving frequency, ω_{drive}, by means of a input force $F_{d,}$ matching the driving frequency, ω_{drive}, with the resonant frequency of an isolated passive mass-spring system comprised of the second and third masses and coupled flexures, and moving the passive mass-spring system to cancel out the input force F_d applied to the first mass, so that maximum dynamic amplification is achieved.

26. The method of claim 15 wherein driving the 2-DOF drive-mode oscillator and driving 2-DOF sense-mode oscillator comprise driving a mass in a drive direction, and sensing motion of a mass in a sense direction, and mechanically amplifying sense direction oscillation amplitudes with a third mass acting as the vibration absorber in the sense-mode oscillator.

27. The method of claim 26 further comprising applying a sinusoidal Coriolis force to a second mass, and matching the frequency of the sinusoidal Coriolis force with a resonant frequency of an isolated passive mass-spring system of the third mass and its coupled flexures, so that the third mass achieves maximum dynamic amplification.

28. The method of claim 15 wherein driving the 2-DOF drive-mode oscillator and driving 2-DOF sense-mode oscillator comprise driving a mass in a drive direction, and sensing motion of a mass in a sense direction, wherein the frequency response of both the drive-mode oscillator and sense-mode oscillator have two resonant peaks and a flat region between the peaks, operating both the drive-mode oscillator and sense-mode oscillator in the flat region of their response curves, and matching the drive anti-resonance frequency, ω_{2x}, of the second mass and sense anti-resonance frequency, ω_{3y}, of the third mass, namely setting $\omega_{3y} = \omega_{2x}$, or equivalently $(k_{3y}/m_3)^{1/2} = (k_{2x}/(m_2 + m_3))^{1/2}$ and determining therefrom the optimal system parameters, together with the optimized ratios $\mu_x = (m_2 + m_3)/m_1$, $\gamma_x = \omega_{2x}/\omega_{1x}$, $\mu_y = m_3/m_2$, and $\gamma_y = \omega_{3y} / \omega_{2y}$, where k_{3y} is the spring constant of the flexures coupled to the third mass, where m_3 is the magnitude of the third mass, k_{2x} is the spring constant of the flexures coupled to the

second mass, m_2 is the magnitude of the second mass, m_3 is the magnitude of the third mass, ω_{1x} is the drive anti-resonance frequency of the first mass, and ω_{2y} is the sense anti-resonance frequency of the second mass.